



National Aeronautics and Space Administration

Airborne Science Newsletter



Winter 2014

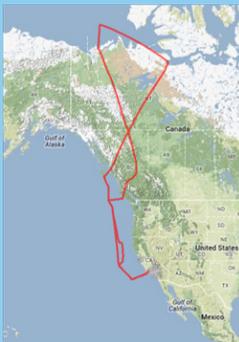
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In Brief ...

Global Hawk flies UAVSAR over Canada and over the Arctic

On 17-18 December 2013, NASA's Global Hawk AV-1 flew 6700 nautical miles (20.8 hours) from EAFB to the Arctic and back, carrying the JPL UAVSAR instrument and the ARC DMS Camera. The UAVSAR was integrated onto the aircraft within the lower fuselage radome area and the DMS Camera was installed in the tail cone. The flight was accomplished with the coordination and cooperation of Canadian airspace and government



Continued on page 4

P-3 flies Operation Ice Bridge from Antarctic Continent

The NASA P-3 Orion, based at the Wallops Flight Facility (WFF), deployed to McMurdo Station, Antarctica on November 11, 2013 for a 22-day mission in support of the Operation IceBridge (OIB) campaign. This deployment marked the first NASA aircraft to be based from the Antarctic continent and the first wheeled aircraft operation based from McMurdo Station. Planning for this campaign began a year and a half prior to deployment. WFF and OIB personnel worked closely with the National Science Foundation (NSF) and the U.S. Air Force (USAF) Air National Guard (ANG) 109th Airlift Wing Polar Operations Office located in Schenectady, NY. NSF and the USAF ANG personnel partnered with NASA to develop operational concepts, provided ice runway training opportunities, and supported site visits to McMurdo Station as well as logistical airlift and surface vessel support to and from Antarctica.

In preparation for deployment, an avionics upgrade was performed on the P-3 flight station to include new Flight Management Systems,

Iridium satellite communication capability (text, data and voice), synthetic vision capability, installation of a Terrain Awareness Warning System (TAWS), and new flight displays. P-3 flight crews performed simulated ice runway training at the U.S. Navy P-3 simulator at NAS Jacksonville, FL as well as the 109th C-130 simulator at Tampa, FL.

WFF and the P-3 Orion supported 128.2 flight hours, flew 5 of the available 7 science flight days (two down days due to weather), and collected over 20,000 km of science data. The payload consisted of four radars from the University of Kansas, two LiDARs and a GPS navigation aid from the NASA Wallops Flight Facility, a Digital Camera System from the NASA Ames Research Center, and a gravimeter and magnetometer instrument managed by Columbia University. The mission demonstrated the feasibility of conducting NASA aircraft operations from the Antarctica continent and allowed data to be collected over longer durations and more area than previously accessible to other scientific research aircraft.

Contributed by Shane Dover



NASA's first ever historic P-3B landing in McMurdo Station, Antarctica on the sea ice runway, which occurred on Nov. 16, 2013.

EV-1 Updates

Projects progress

Five Earth Venture -1 (suborbital) projects, awarded in 2010 with flights beginning in 2011, have all completed more than half of their expected flight hours. In the fall of 2013, HS3, DISCOVER-AQ, CARVE, and AirMOSS all reached major milestones.

HS3

The 2013 Hurricane and Severe Storm Sentinel campaign took place between Aug. 20-Sept. 23, 2013. HS3 used two of NASA's unmanned Global Hawk (GH) aircraft to study Atlantic hurricanes during the deployment at the Wallops Flight Facility. One GH, designated the environmental (AV-6), is designed to sample temperature, humidity, winds, and Saharan dust in the storm environment while the other, designated the over-storm (AV-1), is focused on measuring winds and precipitation within the storm. HS3 conducted seven flights with the environmental GH and two with the over-storm GH.

The Global Hawk operations included the first deployment of both Global Hawks, the first use of the Wallops GH Operations Center (known as GHOC-East), and the first GH back-to-back flights. HS3 proved that GH back-to-back-to-back flights are possible. All of the instruments performed extremely well and HS3 set a record for sondes dropped in one flight (88) and dropped a total of 439 sondes. HS3 flew approximately 273 flight hours. HS3 will fly again in 2014.

DISCOVER-AQ

The second 4-week deployment in 2013 of the Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) was to Houston, Texas, with both the P-3 and LaRC B-200 (King Air). The P-3 carried eight science instruments and the B-200 carried two remote sensors. Sampling focused on the Houston metropolitan area ranging from Conroe in the north to Galveston in the south. The flight path was designed to pass over and complement the air quality information gathered at ground measurement sites operated by the Texas Commission on Environmental Quality and the City of Houston. In addition to the two primary aircraft, an ESTO-supported instrument called

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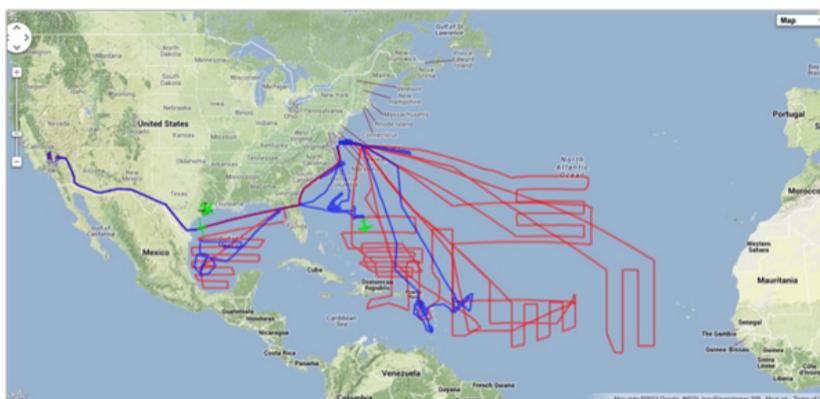
Directors' Corner



Welcome to the ASP Winter 2014 newsletter. We had an incredibly busy year in 2013, and 2014 starts off quickly with January deployments to Iceland (with the G-III/UAVSAR) and Guam (GH's for ATTREX) and then in March we head back to Greenland for Operation IceBridge. I hope everyone had a chance to recharge their batteries and enjoy time off with family and friends, and you're ready to get back to work. I finally got a chance to spend some time (free from the phone and email) thinking about how great it is to be working for NASA and to be a part of Airborne Science. It's been almost four years that have flown by

and I just wanted to let everyone know how proud and lucky I am to be a part of this, and to be around the great people who work in ASP. Unfortunately, we lost another pioneer from ASP, Marty Knutson, on December 11th. Marty was, among other things, godfather of the U-2s (ER-2s), bringing very important high altitude science to NASA. As always, feedback is welcome on the newsletter, the website, our performance, etc., so don't hesitate to contact us with comments and or concerns. Happy New Year!

*Bruce Tagg and Randy Albertson
Airborne Science Program*



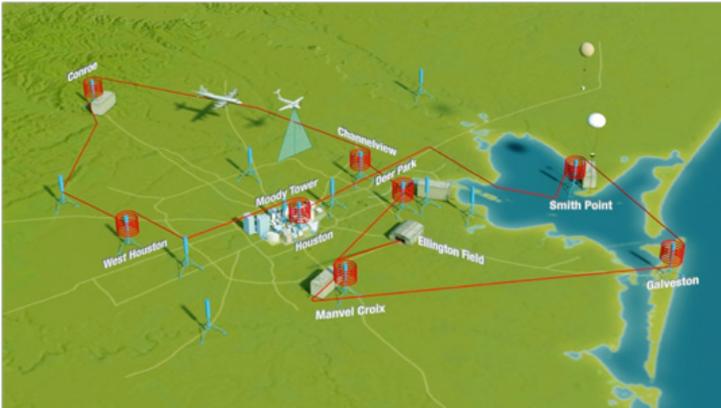
HS3 Flight paths for 2013 (Red tracks are AV-1 and blue tracks are AV-6)



HS3 team with AV-1 and AV-6 at WFF

EV-1 Updates

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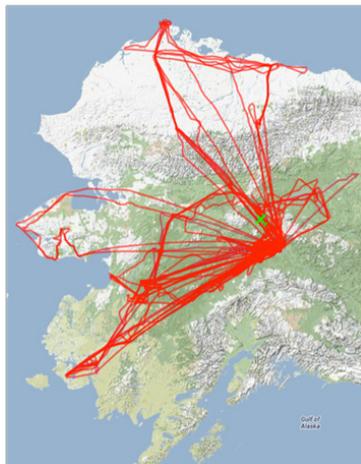
Schematic map of the DISCOVER-AQ 2013 Houston campaign area.

GEO-TASO flew on the HU-25 Falcon for several flight days collecting aerosol and trace gas data relevant for the upcoming TEMPO and GEO-CAPE missions.

During the deployment to Houston, DISCOVER-AQ collaborated with a ship working in the Gulf of Mexico to understand ocean color and atmospheric corrections affecting retrievals. In addition to the eight primary science flights, the King Air flew in support of the ship (sponsored by NASA's GEO-CAPE working group) on three occasions. DISCOVER-AQ Houston also collaborated with SEAC4RS and HS3. The flexibility of ASP helps facilitate these kinds of science collaborations. DISCOVER-AQ will fly again in 2014.

CARVE

The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) mission flies on the Sherpa aircraft, carrying instrumentation to measure atmospheric and surface state parameters to determine carbon budget sensitivity to climate change. New for 2013 was custom navigation and logging system, which time tags and geolocates data from the probes and instruments. The CARVE system was deployed to Fairbanks from April 2 through October 27, 2013. During this entire period, once a month, for a two week period, the CARVE flight crew observed various locations, including the North slope, Barrow, Prudhoe Bay, Nome, Unalakleet, Innoko Valley, Minto Valley, Fort Yukon, Bethel, and Bettles. On July 6, 2013, CARVE exceeded its mission Threshold Requirement of flying 320 science



CARVE 2013 flight tracks, radiating from Fairbanks, AK.

flight hours. The CARVE mission will fly again in 2014 and 2015.

AirMOSS

The AirMOSS mission flew on the JSC G-III in September, October and November, as it had in spring 2013. [AirMOSS was highlighted in the ASP Summer 2013 Newsletter.] AirMOSS will fly again in 2014 and 2015.

ATTREX

ATTREX is scheduled to fly again in January 2014 from Guam.

Contributed by Marilyn Vasques (HS3), Jim Crawford (DISCOVER-AQ), Steve Dinardo (CARVE)

In Memoriam



Martin Knutson
1930 - 2013

Former Director of Flight Operations at NASA Ames and Site Manager of the Ames-Dryden Flight Research Facility

On December 11, 2013, Martin A. Knutson took his final flight. He is joining his best wingman, Jeanine, who is already aloft. Like every flight before, he slipped quietly into his mission. His ground crew, Marty, Eric, Kristin and Robin stood proudly to watch his departure in to the setting sun. Kristin sent him off with "love you" as the last words heard. With a smile on his face, he lowered his visors for the last time and with Godspeed soared into the ever after.

Marty began his aviation career as an aviation cadet in the U.S. Air Force in 1950. Following service in the Korea conflict and participation in developmental test and operation missions in F-84s, he joined the CIA's Air Division flying U-2s. He retired from the Air Force in 1970, having logged over 6,500 hours of flight time. In 1971 Marty joined NASA at the Ames Research Center as manager of the Airborne Instrumentation Research Project. He brought the U-2s to NASA shortly afterward. In 1975 he was named Chief of the Airborne Missions and Applications Division, and served in that position until assuming the position at Dryden. In 1984, Marty was appointed Director of Flight Operations for NASA's Ames Research Center a position he held until 1997.

A memorial service is scheduled at the Officers Club located at NASA AMES Research Park, Mountain View, California, January 25th, 2014 at 1:00.

OCEANIA

Measuring Ocean Color

Ocean Color Ecosystem Assessments with Novel Instruments and Aircraft (OCEANIA) received a Science Innovation Fund award to integrate a novel ocean color observing instrument suite aboard the unmanned aerial vehicle, SIERRA, with the objective of advancing existing calibration and validation protocols for ocean color through concomitant high-accuracy observations of water leaving radiance at the sea surface by the C-OPS radiometer aboard the ship and at 30m by C-AIR radiometer aboard the aircraft and ocean color imagery from overpasses of the AVIRIS instrument aboard the ER-2 (HyspIRI Airborne Simulation Campaign) and the MODIS satellite sensor. Despite the unexpected loss of the SIERRA platform, and with the overwhelming support of key members of the NASA Ames community, the OCEANIA campaign was still able to fly over Monterey Bay, California and capture data from the ongoing red-tide on October 25, 28, 29, 30, 31 and November 5 using the CIRPAS Twin Otter.

The ocean-going and air-based science collection teams are now processing and analyzing the in-water and airborne data and presented preliminary findings during the December 2013 Fall AGU meeting and will present results at the ASLO/AGU- Ocean Sciences meeting in February 2014. The teams are already building a foundation of lessons-learned from the campaign, which will be used going forward on future science missions. The goals and results from OCEANIA fit well with NASA programs such as Ocean Biology and Biogeochemistry, Biodiversity, the HyspIRI

In Brief (continued from page 1)

officials. This was the first flight of the NASA Global Hawk over another country.

Contributed by Dave Fratello and Chris Naffel

- Global Hawk TN 872 is headed to Guam for the 2014 ATTREX mission. Deployment at Anderson AFB is expected through the end of February.

- Launch of the Global Precipitation Measurement (GPM) satellite is set for February 28 from JAXA's Tanegashima Space Center. Post-launch cal/val will use the ER-2 flying from Warner Robbins AFB.



The OCEANIA Team in front of the CIRPAS Twin Otter.

Preparatory Activities, Carbon Cycle and Ecosystems, and Water and Energy Cycle. Principle Investigator Liane Guild, and the entire team, look forward to communicating their results to NASA and the wider ocean color community.

The OCEANIA team is made up of scientists from NASA Ames, NASA Goddard, UC

Santa Cruz, CIRPAS (a U.S. Navy research center), the Monterey Bay Aquarium Research Institute (MBARI) and the San Diego company Biospherical Instruments, who provided the radiometers.

Contributed by Liane Guild and Sherry Palacios

New Scanning L-band simulator instrument

Successful test flights

Goddard's new Scanning L-band Active Passive (SLAP) instrument had its "1st light" flight the week of Dec 2, 2013. SLAP is a new airborne simulator for SMAP, with both passive (radiometer) and active (radar) microwave L-band imaging capabilities. The radiometer observes at 1.4 GHz using duplicate front end hardware from the SMAP satellite radiometer. It also includes a duplicate of the digital backend development unit for SMAP; thus the novel Radio Frequency Interference (RFI) detection and mitigation features and algorithms for SMAP are duplicated with very high fidelity in SLAP. The digital backend provides 4-Stokes polarization capability, just like SMAP.

The key to SLAP's platform flexibility is its thin antenna, ~25cm thick while performing the same conical scanning and 40-degree incidence angle as SMAP. This thin antenna makes SLAP compatible with many aircraft, even those with relatively low ground clearance, for example the B-200 series King Air. SLAP is currently installed on a NASA



Side view of SLAP flying on LaRC UC-12 aircraft.

LaRC UC-12 King Air (NASA has 3 King Airs with compatible nadir ports). SLAP also uses several flight-proven subsystems from the higher-frequency AESMIR instrument—e.g., the azimuth motor. A benefit of using the AESMIR motor assembly is the ability to use the flight-proven AESMIR fairing and modified bomb bay doors to fly SLAP on the NASA P-3B aircraft with minimal installation work. Likewise, SLAP can re-use a flight-proven

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ASP at AGU

Airborne Science Program has a strong presence at recent Fall Meeting in San Francisco

The Airborne Science Program was well represented at the Fall Meeting of the American Geophysical Union in San Francisco in December. NASA hosted a major exhibit booth highlighting all areas of NASA Science, including the Airborne Science Program. During the 5-day meeting, thousands of attendees visited the booth, not only to carry away posters, calendars and tote bags, but also to interact with representatives from all Science programs. NASA also sponsored on-site Earth Science lectures, including an Airborne Science presentation at the Hyperwall. Many technical session posters and science talks featured activities and outcomes of airborne experiments, including Operation IceBridge, Earth Venture projects and both manned and unmanned aircraft missions. In addition, eleven posters were presented by students who participated in SARP 2013.

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ASP Deputy Program Manager Randy Albertson briefs attendees on aircraft available to the NASA Earth Science community as well as cross-cutting capabilities at the NASA Hyperwall during the 2013 AGU Fall meeting.

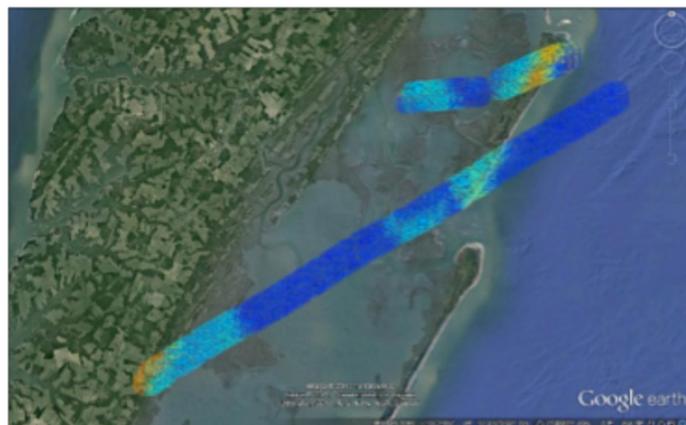
SLAP

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AESMIR installation design to fly on C-130s. Other potential aircraft platforms for SLAP are the Sherpa and Twin Otter.

SLAP's initial flights were conducted in December 2013 over the eastern shore of Maryland and successfully demonstrated radiometer imaging over two full SMAP 36x36 km grid cells at 1km resolution within 3 hrs, easily meeting the SMAP post-launch cal/val airborne mapping requirements. A second flight on the same day also demonstrated SLAP's quick-turn abilities and high-resolution/wide-swath capabilities with 200m resolution across a 1500m swath from 2000 ft AGL.

The radar will be turned on during future test flights as soon as NASA and the FAA agree on a spectrum coordination plan for several instruments operating in this portion of the spectrum. SMAP launch is in Nov, 2014 and SMAP is considering one post-launch



First light image from the DelMarVa peninsula along the Atlantic coast. The colors in this uncalibrated image correspond to L-band brightness temperatures from SLAP's radiometer. Reds & yellows correspond to warmer land while dark blues correspond to water and light blues correspond to shallow water/mud flats.

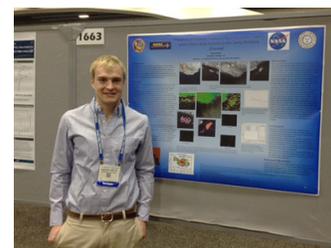
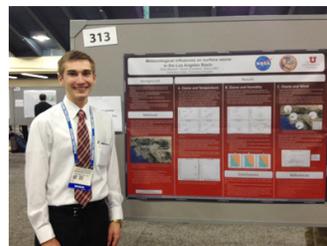
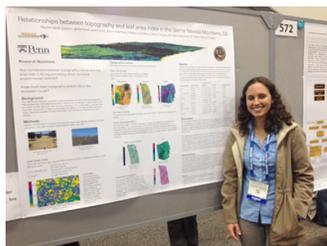
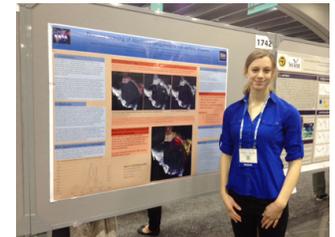
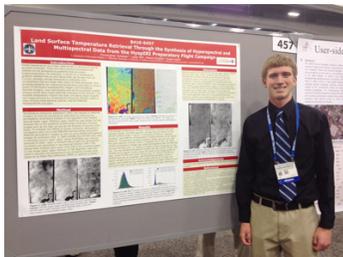
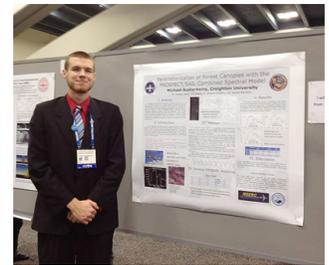
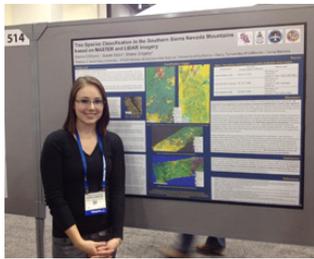
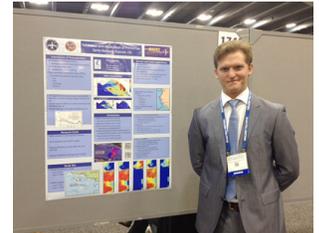
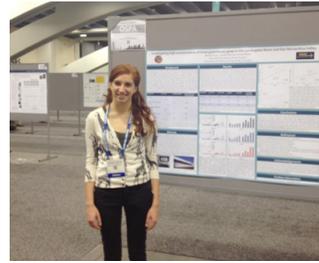
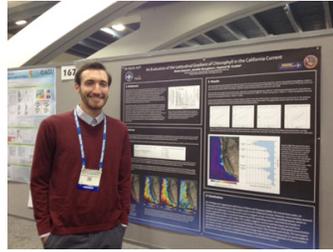
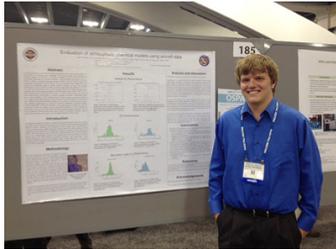
calibration/validation campaign. SLAP should be ready by mid-2014 to provide its unique SMAP simulation capabilities for any SMAP-related campaigns or for observations of soil

moisture, soil freeze/thaw, sea ice, ice sheets, or ocean science that requires L-band sensing.

Contributed by Edward Kim

ASP at AGU

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Eleven undergraduate students from the NASA Airborne Science Program's 2013 Student Airborne Research Program (SARP) summer internship presented the results of their SARP summer research in scientific sessions at the 2013 American Geophysical Union Fall Meeting in San Francisco, December 9-13, 2013. (Photos courtesy Emily Schaller.)

NASA SMD ESD Airborne Science Program 6-Month Schedule

SUPPORTED	Jan	Feb	Mar	Apr	May	June
DC-8	DC-8 at Heavy C Check Facility		DC-8 at Palmdale DAOF post Heavy C	Post Heavy C	ACCESSII FR148003	SARP SARP
ER-2 #806	Maint.	HSRL	HSRL Test Fl	HyspIRI	LAC	GRC-PV HyspIRI LAC
ER-2 #809	600-Hr Inspection/Maintenance			AMPR	IPHEX Deployment Warner Robins	Gmd Crew RTN to DFRC
G-III (D)	Maint. Mex. CA Sci Iceland	Scheduled Maintenance		Central & South Amer.	CA Sci Iceland/Norw	CA Sci Flts Sched Maint
G-III (J)	992 Maint.					
G. Hawk #871	NGC Upload (Tentative)					HS3
G. Hawk #872	ATTREX 872 A	ATTREX Deployment - Guam			ATTREX Flights	ATTREX HS3
P-3	Maintenance	OIB Upd OIB Upd	Operation Ice Bridge		Post Mission	DISCOVER-AQ Upd
OTHER	Jan	Feb	Mar	Apr	May	June
UC-12		Phase 3 & 4 Inspection	CALIPSO Cal/Val	SLAP Spring 2014 Campaign		HSRL-OBB
B200 (D)	AirSW AirSW	AirSWOT Hydro	AirSWOT Sac to River/Santa Barbara Coast	ISRNET Int.	SRNET	
B200 (L)	Two Micron LIDAR					Phase Inspection
B200						
C-130 Hercules						
C-23 Sherpa	CARVE CARV CARVE		CARVE	CARVE CARVE	CARVE CARVE Mission	CARVE Mission CARVE Mzn
Cessna					Annual Inspection	
Falcon/HU-25C		ACES	B Check	ACCESS 2		GEO-TASO
Ikhana	Local Flights					
Lear 25		NAMS		NAMS		
S-3B		UAS in the NAS		Flight Testing		Flight Testing
SIERRA						
T-34C			UAS in the NAS			UAS in the NAS UAS in NAS
T. Otter	inspec	Remote Sensing				
UH-1				Range Surv		
WB-57 #926						
WB-57 #928	Major Ops Inspection					
WB-57 #927	Acceptance Insp					
COMMERCIAL AIRCRAFT						
Proteus						
Twin Otter International	Reising IIP					

= Foreign Deployment
 = Stateside Deployment
 = Aircraft Modifications
 = Reimbursable
 = Maintenance
 = Flight
 = Deployment Milestone

For an up-to-date schedule, see http://airbornescience.nasa.gov/aircraft_detailed_cal

ASP Upcoming Events

- * AIAA SCI-TECH 2014
National Harbor, MD
January 13-17, 2014
<https://www.aiaa.org/scitech2014/>
- * 3rd SWOT SDT meeting,
Jan. 14-16, 2014, Arlington, VA
<https://www.joss.ucar.edu/meetings/2014-nasa-cnec-swot-sdt-meeting>
- * PARCA 2014 Program for Arctic Regional Climate Assessment
January 28, 2014; GSFC
Operation IceBridge (OIB) Workshops & Science Team Meeting
January 29-30, 2014; GSFC
Contact: charles.web@nasa.gov
- * AIAA SCI-TECH 2014
National Harbor, MD
January 13-17, 2014
<https://www.aiaa.org/scitech2014/>
- * American Meteorological Society Annual Meeting
February 2-6, 2014, Atlanta, GA
<http://annual.ametsoc.org/2014/>
- * 2014 AGU Ocean Sciences meeting
February 23-28, 2014; Honolulu, Hawaii
<http://www.sgmeet.com/osm2014/default.asp>
- * 214 IEEE Aerospace Conference
Big Sky, Montana
- March 1-8, 2014
<http://www.aeroconf.org/>
- * ASPRS 2014 Annual Conference
March 23-27, 2014
Louisville, Kentucky
<http://conferences.asprs.org/Louisville-2014/blog>
- * American Meteorological Society
31st Conference on Hurricanes and Tropical Meteorology
San Diego, California
March 31-April 4, 2014
<http://www.ametsoc.org/MEET/meetinfo.html>

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Airborne Science Program Platform Capabilities

Available aircraft and specs



Airborne Science Program Resources	Platform Name	Center	Duration (Hours)	Useful Payload (lbs.)	GTOW (lbs.)	Max Altitude (ft.)	Airspeed (knots)	Range (Nmi)	Internet and Document References
ASP Supported Aircraft	DC-8	NASA-DFRC	12	30,000	340,000	41,000	450	5,400	http://airbornescience.nasa.gov/aircraft/DC-8
	ER-2	NASA-DFRC	12	2,900	40,000	>70,000	410	>5,000	http://airbornescience.nasa.gov/aircraft/ER-2
	Gulfstream III (G-III) (C-20A)	NASA-DFRC	7	2,610	69,700	45,000	460	3,400	http://airbornescience.nasa.gov/aircraft/G-III_C-20A_-_Dryden
	Gulfstream III (G-III)	NASA-JSC	7	2,610	69,700	45,000	460	3,400	http://airbornescience.nasa.gov/aircraft/G-III_-_JSC
	Global Hawk	NASA-DFRC	30	1900	25,600	65,000	345	11,000	http://airbornescience.nasa.gov/aircraft/Global_Hawk
	P-3B	NASA-WFF	14	14,700	135,000	32,000	400	3,800	http://airbornescience.nasa.gov/aircraft/P-3_Orion
Other NASA Aircraft	B-200 (UC-12B)	NASA-LARC	6.2	4,100	13,500	31,000	260	1,250	http://airbornescience.nasa.gov/aircraft/B-200_UC-12B_-_LARC
	B-200	NASA-DFRC	6	1,850	12,500	30,000	272	1,490	http://airbornescience.nasa.gov/aircraft/B-200_-_DFRC
	B-200	NASA-ARC/DOE	6.75	2,000	14,000	32,000	250	1,883	http://airbornescience.nasa.gov/aircraft/B-200_-_DOE
	B-200	NASA-LARC	6.2	4,100	13,500	35,000	260	1,250	http://airbornescience.nasa.gov/aircraft/B-200_-_LARC
	C-23 Sherpa	NASA-WFF	6	7,000	27,100	20,000	190	1,000	http://airbornescience.nasa.gov/aircraft/C-23_Sherpa
	Cessna 206H	NASA-LARC	5.7	1,175	3,600	15,700	150	700	http://airbornescience.nasa.gov/aircraft/Cessna_206H
	Dragon Eye	NASA-ARC	1	1	6	500+	34	3	http://airbornescience.nasa.gov/aircraft/B-200_-_LARC
	HU-25C Falcon	NASA-LARC	5	3,000	32,000	42,000	430	1,900	http://airbornescience.nasa.gov/aircraft/HU-25C_Falcon
	Ikhana	NASA-DFRC	24	2,000	10,000	40,000	171	3,500	http://airbornescience.nasa.gov/aircraft/Ikhana
	Learjet 25	NASA-GRC	3	3,200	1,500	45,000	350	1,200	http://airbornescience.nasa.gov/aircraft/Learjet_25
	S-3B Viking	NASA/GRC	6	12,000	52,500	40,000	450	2,300	http://airbornescience.nasa.gov/aircraft/S-3B
	SIERRA	NASA-ARC	10	100	400	12,000	60	600	http://airbornescience.nasa.gov/platforms/aircraft/sierra.html
	T-34C	NASA-GRC	3	500	4,400	25,000	75	700	http://airbornescience.nasa.gov/aircraft/T-34C
	Twin Otter	NASA-GRC	3	3,600	11,000	25,000	140	450	http://airbornescience.nasa.gov/aircraft/Twin_Otter_-_GRC
WB-57	NASA-JSC	6	6,000	63,000	60,000+	410	2,500	http://airbornescience.nasa.gov/aircraft/WB-57	

ASP Upcoming Events

Continued from page 7

- * SMAP 3rd Applications Workshop
April 9-10 2014; Boulder, CO
<https://www.signup4.net/Public/ap.aspx?EID=3RDS10E>
- Noordwijk, The Netherlands; May 5-7, 2014
Call for papers is open, abstracts due 1 February 2014
<http://congrexprojects.com/2014-events/14c02/>
- * IEEE International Geoscience and Remote Sensing Symposium (IGARRS) 2014
July 13-18, 2014; Quebec City, Canada
Call for papers is open; abstract due January 13, 2014
<http://www.igarss2014.org/>
- * NASA LCLUC Spring Science Team Meeting
April 23–25, 2014; Rockville, Maryland
<http://lcluc.umd.edu/meetings.php?mid=52>
- * ICESAT-2 / Landsat 8 Joint Vegetation Tutorial
May 7-8, 2014; University of Michigan, Ann Arbor, Michigan
<http://icesat.gsfc.nasa.gov/icesat2/apps-events.php>
- * SPIE 2014 Remote Sensing
Amsterdam; September 22 – 25, 2014
CALL for PAPERS is open, abstracts due 31 March
http://spie.org/x6262.xml?WT.mc_id=RERS14CE
- * 10th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-10); and “Future GHG Mission Challenges Workshop”